JORDAN

Influence of Alum and Soap Solutions on the Permeability of Concrete

Civil Engineering

B. S.

1909

INFLUENCE OF ALUM AND SOAP SOLUTIONS ON THE PERMEABILITY OF CONCRETE

BY

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THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

IN THE

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED, JUNE, 1909

UNIVERSITY OF ILLINOIS

June 1, 1909

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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ENTITLED **INFLUENCE OF ALUM AND SOAP SOLUTIONS ON THE PERMEABILITY OF CONCRETE**

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF **Bachelor of Science in Civil Engineering**

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INFLUENCE OF SOAP AND ALUM SOLUTIONS ON THE PERMEABILITY OF CONCRETE.

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Introduction.

Methods of Waterproofing.

Preparation.

Why subject was investigated.

Materials Used.

Tables.

Apparatus.

Description.

Drawing.

Methods of Proportioning.

Volumetric Tests.

Method.

Table of Results.

Results of Percolation Tests.

Tables.

Curves.

Conclusions.

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INTRODUCTION.

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When concrete is used in foundations, in the linings of tunnels, in dams, or in reservoirs, it is desirable that the concrete be impervious to water or nearly so. Many methods have been suggested and tried. In some the cost is prohibitory, in others skilled workmen are necessary, and in others the process is effective at first but does not stand the test of time. All the methods that have been suggested for making concrete impermeable may be grouped under four heads, namely;

(1.) By accurately grading and proportioning the aggregates and the cement in the concrete.

(2.) By special treatment of the surface of the concrete.

(3.) By the introduction of foreign ingredients in the concrete.

(4.) By the application of waterproofing material such as, a layer of asphalt and felt or a steel diaphragm imbedded in the concrete, or a coat of asphalt and felt applied to the surface of the concrete.

Concrete can be made impervious by the first, second or fourth method but the cost is likely to be excessive and the methods are not always applicable. The third method gives promise of being satisfactory if ingredients can be found which will give uniform and reliable results without being too costly. The object of this method is to fill the voids in the concrete, and some of the ingredients used for this purpose consist of very finely pulverized

materials which do not in any way effect the setting of the cement. They are Puzzolan cement, pulverized rock, hydrated lime, and metallic stearates. An insoluble precipitate is formed in the voids by other ingredients such as aluminum sulphate, oil emulsions, chloride of lime, and alum and soap.

As none of the above ingredients have given entire satisfaction it was the purpose of the author to further investigate the use of alum and soap as a cheap waterproofing compound in a concrete composed of 1 part of cement, 2 parts of sand, and 4 parts of crushed limestone.

Before starting the tests in the laboratory the following references to the use of soap and alum as a waterproofing compound were consulted to learn how much had been done on the subject and the methods used by the different investigators. Professor Hatt of Purdue University used a mortar composed of 1 part cement and 2 1/2 parts bituminous ash. One half the water contained a 5% solution of alum and the other half a 7% solution of soap. The alum solution was added first. He reported a decrease of 50 % in absorption (Transactions of the American Society of Civil Engineers, Volume 51 page 129 and 128). Mr. Cunningham in the same volume of the transactions reports the use of powdered alum equal to 1 % of the combined weight of the sand and cement, and yellow soap in 1 % solution. Major W. L. Marshal used 1 part cement 2 1/2 parts sand and added 3/4 of a pound pulverized alum(dry) to each cubic foot of sand, then

water in which had been dissolved 3/4 of a pound of soft soap per gallon of water. This is reported as giving satisfactory results. (Report of Chief Engineer U. S. A. 1901 page 918).

The report of the Laboratory of Structural-Materials Testing at St. Louis, Mo., and the Engineering News, and the Engineering Record for the years 1907 and 1908 were consulted regarding apparatus and methods of proceedure. The names of materials used as waterproofing compounds and their classification were obtained from Taylor and Thompsons Plain and Reinforced Concrete and from the Proceedings of the Engineers Club of Philadelphia, Oct. 1908.

MATERIALS USED.

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The materials used in the tests were Wabash river sand, Kankakee crushed lime stone, Chicago A A Portland cement, alum such as could be procured at any drug store, and Lenox soap. The maximum size of the sand and stone was 0.2 inch.

The physical tests of the cement are given in Table I, those of the sand in Table II, and those of lime stone in Table III. The specific gravity of alum was 1.77 and that of soap was 1.05.

Table I

TEST OF CEMENT.

Fineness			Tensile Strength					
Sieve	Amount Retained		7 Day Test Breaking load, Lbs.			28 Day Test Breaking load, Lbs.		
Number.	In Grams	In %	No.	Neat.	1:3 Mortar	No.	Neat	1:3 Mortar.
20	0.0	0.00	1	710	210	1	785	250
75	21.8	2.18	2	720	180	2	820	220
100	37.9	3.79	3	700	195	3	720	290
200	230.6	23.06	4	740	190	4	785	240
Pan.	709.7	70.97	5	640	180	5	790	225
Total	1000.0	100.00	Average	702	190	Average	790	245
Specific Gravity 3.154			For Normal Consistency 20 % of Water.					

Table II

SIEVE ANALYSIS OF SAND.

Amount Used.	Sieve Number	Amount Retained	
		Grams	%
1000 gr.	.2 in.	0.0	0.00
	5	29.0	2.90
	8	83.9	8.39
	10	90.0	9.00
	16	258.0	25.80
	20	58.3	5.83
	30	216.7	21.67
	40	107.2	10.72
	60	106.9	10.69
	74	19.4	1.94
	100	20.8	2.08
	150	0.5	0.05
	200	2.0	0.20
	Pan	7.4	0.74
Specific Gravity 2.627			

Table III

SIEVE ANALYSIS OF LIMESTONE

Amount Used	Sieve Number	Amount Retained	
		Grams	%
1000 gr.	.2 in.	0.00	0.00
	5	164.5	16.45
	8	174.3	17.43
	10	102.2	10.22
	16	192.1	19.21
	20	23.7.0	2.37
	30	67.9	6.79
	40	39.0	3.90
	60	41.7	4.17
	74	12.9	1.29
	100	24.0	2.40
	150	27.0	2.70
	200	12.8	1.28
	Pan	116.6	11.66
Specific Gravity 2.731			

APPARATUS.

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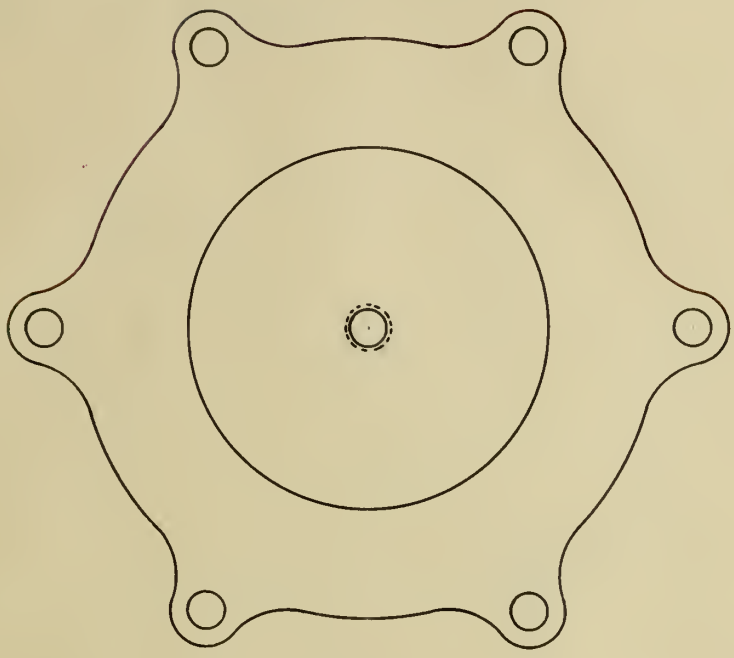
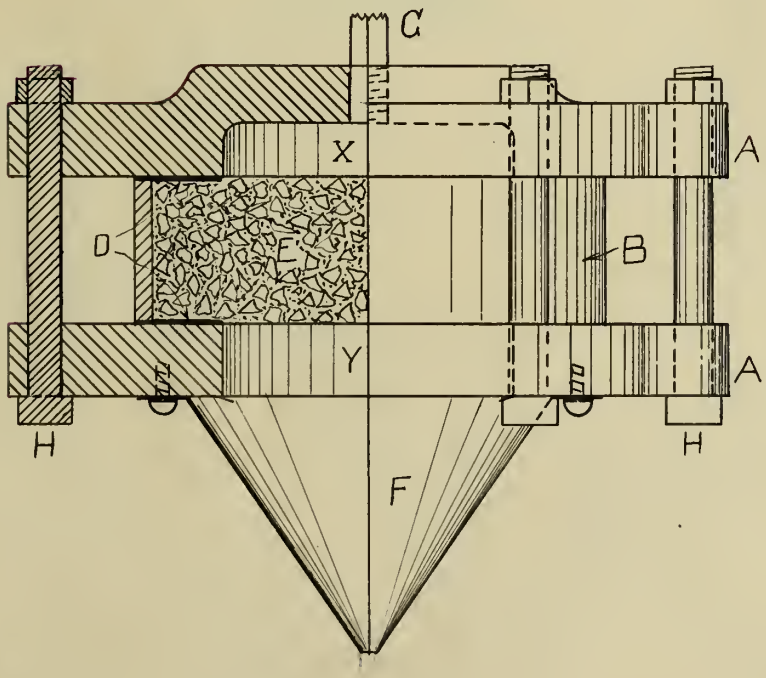
The apparatus in which the disks were tested was modeled after that in use at the Structural-Materials Testing Laboratory at St. Louis, Mo. Fig. 1 shows the apparatus and the method of holding the test specimens. A and A are two cast iron plates with holes near the edge through which six 1/2 inch bolts as at H are inserted for the purpose of clamping the plates tight against the test specimen. C is a 1/2 inch pipe which connects the apparatus with the mains of the University water system from which the pressure was obtained. The average daily pressure was 45 pounds per square inch , although there was considerable variation at times. The pipe C opened into a circular cavity X in the bottom side of the top casting. This opening exposes to the pressure of the water a circular area of the concrete 4 inches in diameter. A circular opening Y 4 inches in diameter extending through lower casting allowed the water which percolated through the test specimen to be collected by the funnel F which opened into a 500 c.c. graduate. E is the test specimen which was moulded in a two inch length of six inch gas pipe B. The rubber gasket at D, were placed between the plates on one side and the mould and test specimen on the other so that a water tight joint could be obtained. Any leakage between the test specimen and the mould was prevented by placing a thin layer of asphalt about 3/4" wide and 1/8" thick under the gaskets so

Figure I



Top View



Section Side View

PERMEABILITY APPARATUS

that when the plates were tightly clamped together the asphalt was forced into the openings.

METHOD OF PROPORTIONING.

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The sand and limestone were proportioned in the ratio of their weight and the soap and alum in percent of their weights to that of the cement.

The soap was dissolved in water and in this condition it was added to the aggregates. Two methods were used in adding the alum: (1) when it was in a dry powdered condition and (2) when it was dissolved in water. In the first case the alum was added to the cement and thoroughly mixed. In the second case the alum in solution was added after all the aggregates had been thoroughly mixed. All the mixing was done in a galvanized pan with a 4 inch trowel. The concrete was tamped into the mould in 1/2 inch layers with an iron tamper 1 1/2 inches in diameter. The moulds were carefully oiled to permit the removal of the test specimen after the pressure tests were run, thus allowing the moulds to be used again.

The surface upon which the test specimens were made was oiled to prevent adhesion and to facilitate the removal of the disks. The test specimens were covered by a damp cloth and were left on the oiled surface for 24 hours and then were placed in a moist chamber for 6 days. When the test specimens were 7 days old, they were placed in the apparatus and the water pressure turned on. Readings of the quantity of water passing through the disks were taken every 24 hours.

VOLUMETRIC TESTS.

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A volumetric test was made to determine the percent of voids in each specimen. The steps in the operation are as follows. The mixing including a trowel, tamper, and a piece of cotton waste which was used to wipe up the water that flushed out around the bottom of the mould, were carefully weighed. The materials for a test specimen were mixed care being taken that none was lost in the process. From 3 to 5 minutes was required to thoroughly mix the concrete, the time depending upon the percent of water and soap present. An increase in the percent of soap and a decrease in the percent of water had the same effect - that of causing the mixture to be dryer thus necessitating longer working to bring it to the required consistency. After the mould was tamped level full, the water and surplus concrete were wiped up and returned to the mixing pan. Then the mixing pan which contained the unused concrete and the tools was again weighed. The difference between the first and second weight of the mixing pan and its contents gave the amount of the concrete which was used. The diameter and thickness of the moulds were measured before they were used and the volume computed. The actual weights of the materials in the mould were computed by the ratio of the materials in the specimen to that which was weighed into the mixing pan. The computed volumes of the materials were found by dividing the proportionate weights of the materials by

their specific gravity. The volume of the mould minus the computed volume of all the materials in the test specimen gave the actual amount of voids. The actual voids divided by the volume of the mould and multiplied by 100 gave the percent of voids. The percent of voids in each specimen are shown in Table IV.

Table IV.

VOLUMETRIC TESTS

No	Weight of Material in Grams: Cement	Sand	Stone	Water	Soap	Alum	Total Material	Remaining Concrete	Concrete in Disk	Proportionate Weight in Grams: Cement	Sand	Stone	Water	Soap	Alum	Dimensions of Disk: Diameter in cm.	Height in cm.	Volume in cu. cm.	Computed Volumes in Cu. Cm.: Cement	Sand	Stone	Soap	Alum	Total	Voids in %
1	357	714	1429	250	0	0	2750.0	540	2210.00	286.6	573.34	1147.49	200.75	0	0	5.1	15.6	974.78	90.89	218.24	420.17	0	0	729.30	25.28
2	357	714	1429	250	0	0	2750.0	490	2260.00	293.10	586.20	1173.21	205.25	0	0	5.1	15.6	974.78	92.92	223.14	429.59	0	0	745.65	22.50
3	357	714	1429	250	2.5	12.5	2765.0	615	2150.00	277.39	554.78	1110.31	194.25	1.94	9.71	5.1	15.6	974.78	87.94	211.18	406.56	1.94	5.61	703.25	26.81
4	357	714	1429	250	2.5	12.5	2750.0	585	2165.00	279.38	558.77	1117.54	196.75	1.98	9.84	5.1	15.6	974.78	88.58	212.70	409.20	1.94	5.68	718.14	26.33
5	357	714	1429	250	2.5	2.5	2755.0	650	2105.0	272.75	545.50	1091.76	191.00	1.91	1.91	5.05	15.5	952.89	86.87	207.65	399.76	1.90	1.10	697.28	26.80
6	357	714	1429	250	2.5	1.75	2754.25	590	2164.2	280.25	560.49	1121.77	196.25	1.96	1.35	5.1	15.6	974.78	88.85	213.35	410.75	1.96	.77	715.68	26.58
7	330	660	1320	277	2.77	1.39	2591.16	3.05	2286.1	291.06	582.12	1164.24	244.31	2.44	1.22	5.1	15.6	974.78	92.28	221.59	426.30	1.22	1.40	742.79	23.73
8	330	660	1320	254	2.54	1.27	2567.81	310	2257.8	290.07	580.14	1160.28	223.27	2.23	1.11	5.1	15.6	974.78	91.96	220.83	424.85	1.11	1.28	739.83	24.10
9	330	660	1320	254	5.08	2.54	2571.62	370	2201.6	282.48	564.96	1129.92	217.42	4.34	2.17	5.1	15.6	974.78	89.56	215.55	413.88	2.17	2.50	723.66	25.77
10	330	660	1320	254	3.81	1.90	2569.71	370	2199.7	282.48	564.96	1129.92	217.42	3.26	1.63	5.1	15.6	974.78	89.56	215.55	413.88	1.63	1.88	722.50	25.91
11	330	660	1320	254	7.62	3.81	2575.43	360	2215.4	287.10	574.20	1184.40	220.98	6.63	3.31	5.1	15.5	962.33	91.14	218.32	420.65	3.83	3.31	737.25	23.38
12	330	660	1320	254	10.16	5.08	2579.24	390	2189.2	280.50	561.00	1122.00	215.90	8.64	4.32	5.1	15.4	949.95	89.04	213.30	410.98	4.99	4.32	722.63	23.92
13	330	660	1320	254	7.62	3.81	2575.43	400	2175.4	277.20	554.40	1108.80	213.36	6.40	3.20	5.08	15.65	977.19	88.00	210.79	406.15	3.70	3.20	711.94	22.80
14	330	660	1320	254	7.62	3.81	2575.43	360	2215.4	283.47	566.94	1133.88	218.19	6.54	3.27	5.1	15.7	987.32	89.99	215.56	415.34	6.23	1.85	728.97	26.16
15	330	660	1320	254	10.16	5.08	2579.24	330	2249.2	287.10	574.20	1148.40	220.98	8.84	4.42	5.1	15.6	974.78	91.11	218.32	420.66	6.11	4.42	739.62	24.08
16	330	660	1320	254	10.16	5.08	2579.24	340	2239.2	286.44	572.88	1145.76	220.47	8.89	4.42	5.1	15.5	962.33	90.93	217.82	419.69	5.11	4.42	739.93	22.98
17	330	660	1320	277	2.77	2.77	2592.54	425	2167.5	275.88	551.76	1103.52	231.57	2.32	2.32	5.1	15.55	968.66	87.89	209.79	404.22	1.34	2.32	705.56	24.70
18	330	660	1320	277	1.39	2.77	2591.65	435	2156.2	274.56	549.12	1098.24	230.46	1.15	2.30	5.08	15.5	958.55	87.16	208.79	402.28	1.09	1.30	700.62	26.91
19	330	660	1320	277	2.77	0	2589.77	400	2189.7	287.85	557.70	1114.40	234.07	2.77	0	5.1	15.6	974.78	88.52	212.05	408.20	2.77	0	711.54	27.00
20	330	660	1320	277	0	0	2587.0	370	2217.0	288.81	565.62	1131.24	237.39	0	0	5.08	15.65	977.19	89.78	215.05	419.37	0	0	719.20	26.41
21	330	660	1320	277	2.77	1.39	2591.15	360	2231.2	284.13	568.26	1136.52	238.50	2.77	1.19	5.1	15.7	987.32	89.78	216.07	416.30	2.77	.68	725.60	26.57
22	330	660	1320	277	1.39	.69	2589.08	410	2179.1	277.53	555.06	1110.12	232.96	1.39	.58	5.08	15.5	958.55	88.10	211.06	406.63	1.39	.34	707.51	26.50
23	330	660	1320	277	1.39	.69	2589.08	400	2189.1	278.85	557.70	1115.40	234.07	1.39	.58	5.1	15.6	974.78	88.52	212.05	408.57	1.39	.34	710.87	27.08
24	330	660	1320	277	0	0	2587.00	365	2222.0	283.47	566.94	1133.88	237.94	0	0	5.08	15.65	977.19	89.97	215.56	415.34	0	0	720.89	26.40
25	330	660	1320	277	0	0	2587.00	377	2210.0	278.57	557.04	1114.08	233.79	0	0	5.1	15.6	974.78	88.41	211.80	408.09	0	0	708.30	27.34
26	330	660	1320	277	6.6	3.3	2596.90	475	2121.9	269.61	539.22	1078.44	226.31	5.39	2.69	5.1	15.5	962.32	85.59	205.02	394.66	5.13	1.52	691.92	28.09
27	330	660	1320	277	2.77	0	2589.77	430	2159.8	274.56	549.12	1098.20	230.46	2.30	0	5.1	15.6	974.78	87.16	208.79	402.28	2.19	0	700.42	28.12
28	330	660	1320	277	9.9	4.95	2601.85	496	2106.8	267.30	534.60	1069.20	224.37	9.00	4.50	5.08	15.66	977.19	84.85	203.27	391.63	8.59	2.54	690.88	29.91

RESULTS AND CONCLUSIONS.

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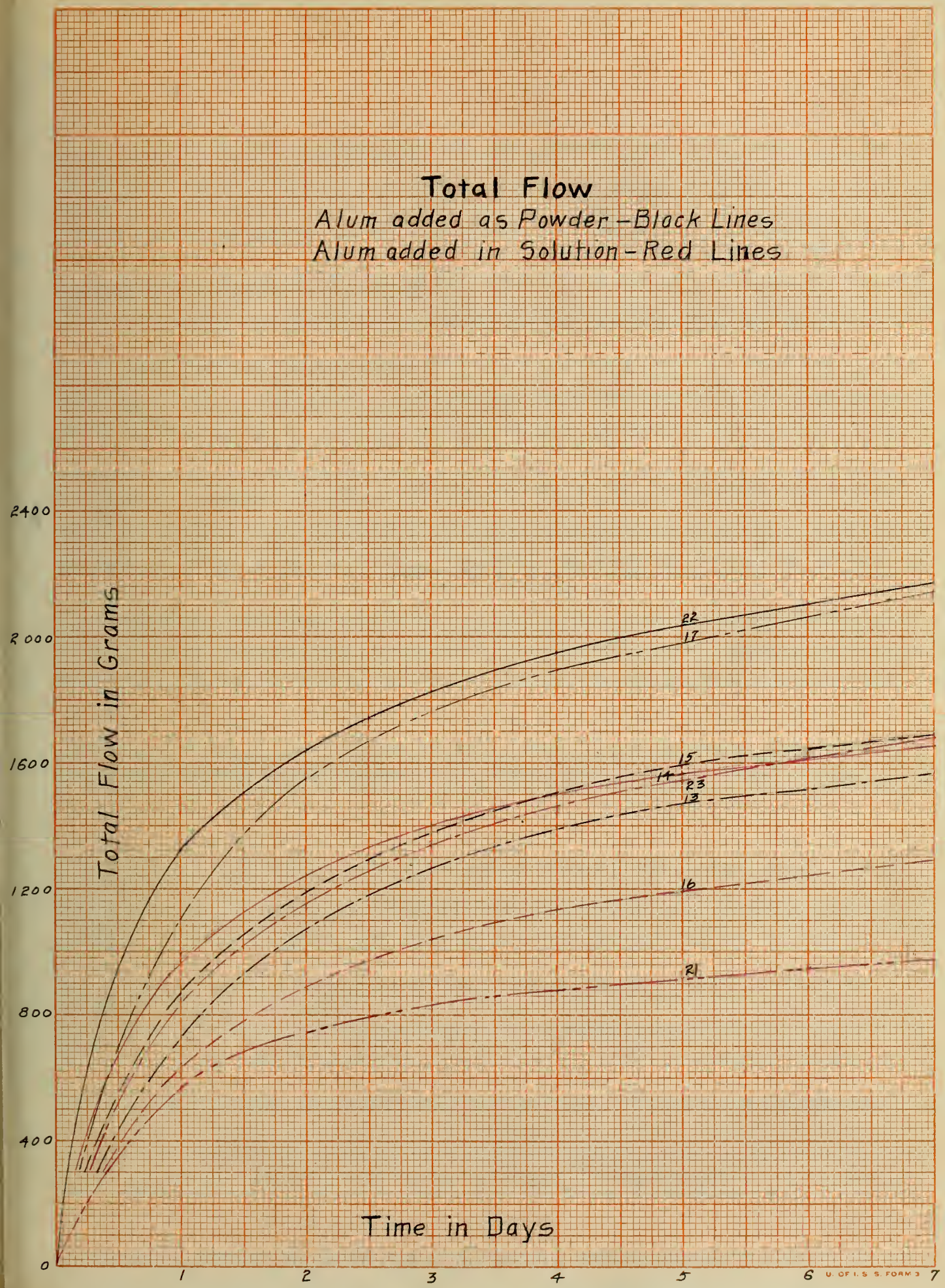
The results of the percolation tests are given in Table V those tests marked with stars had the alum in solution when mixed and the unmarked specimens had the alum added in the powdered form. The latter method of adding the alum was used by Major Marshal is mentioned on page 3 and was chosen by the author on the supposition that the alum would thus be more uniformly distributed though the mass for its combination with the soap in forming an insoluble precipitate. The curves on pg. 18 for the total flow and on page 19 for the daily percolation show that the alum in solution gave better results than powdered alum. The black lines show the percolation of the specimens made with powdered alum and the red lines of the same construction represent the specimens made with the alum in solution. Two specimens of exactly the same percent and amount of soap and alum were used in each case. The pairs are Nos. 13 and 14, 15 and 16, 17 and 21, and 22 and 23. The first named of each pair contained the powdered alum and the second the alum in solution. With the exception of No. 14 the specimen containing the solution showed less percolation than those containing the alum added as a powder.

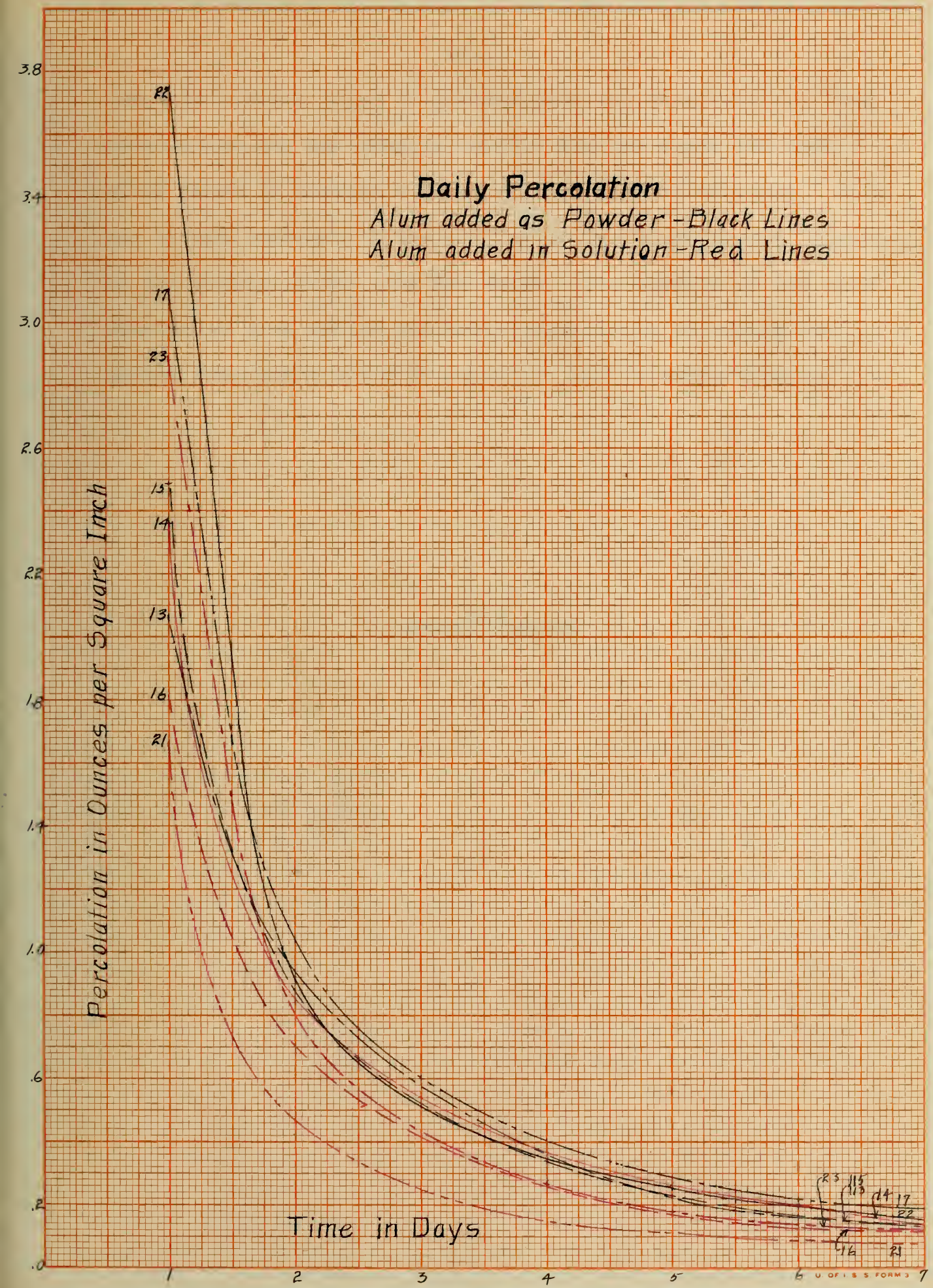
It is readily seen by a comparison of the first six tests in Table V with those following that the percent of water has a direct bearing upon the permeability of the concrete and

Table V.

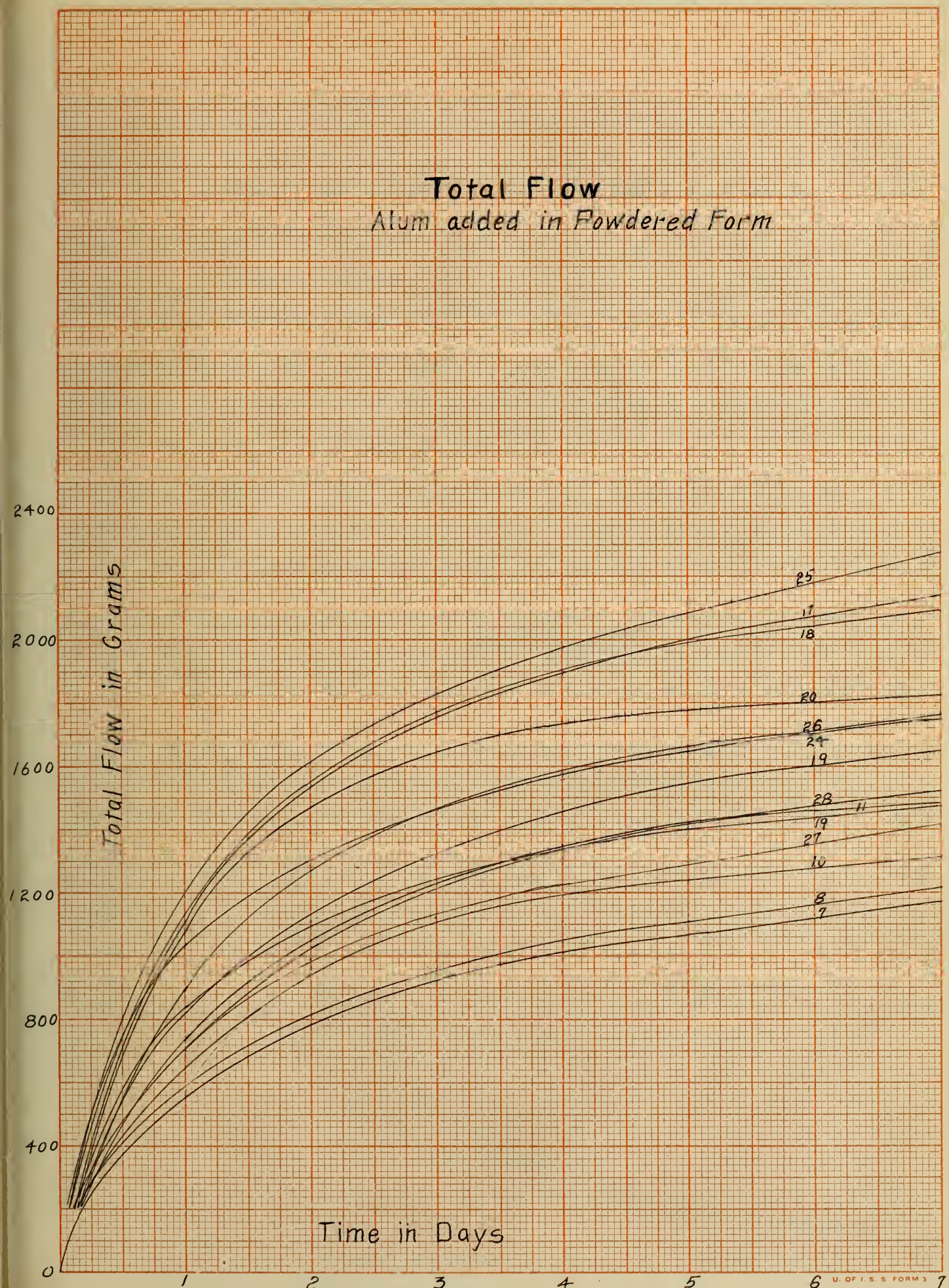
PERCOLATION TESTS

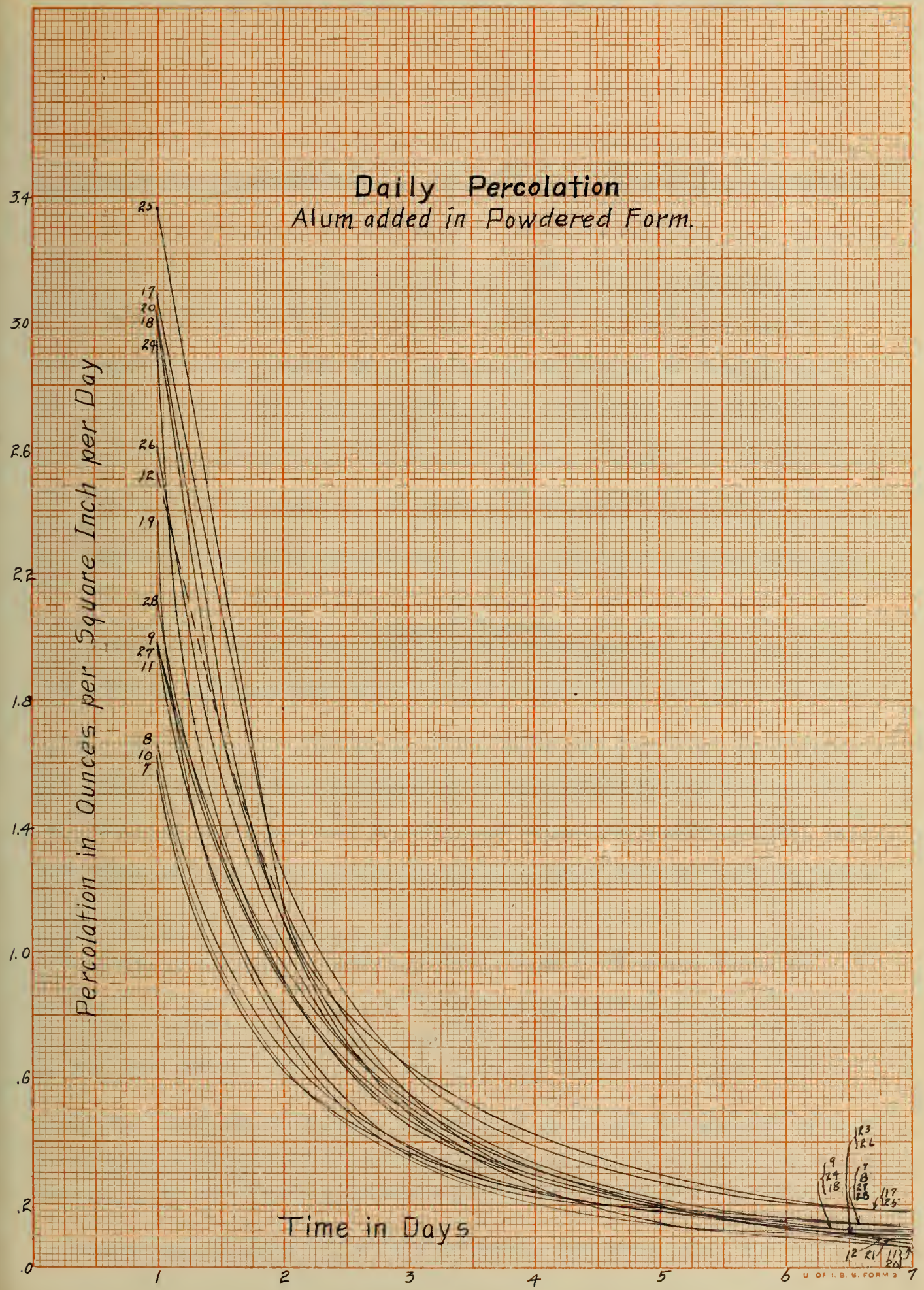
No of Disk	Waterproofing in % of Cement: Soap	Alum	Water in % of Aggreg.	Voids in Per Cents	Date Test Started	Water Passing Through Disks in Grams per Day: 1st	2nd	3rd	4th	5th	6th	7th	Percolation in Ounces per Square Inch per Day: 1st	2nd	3rd	4th	5th	6th	7th	Total
1	0.00	0.00	10	25.18	1/30/09	Large quantities														
2	0.00	0.00	10	22.50	do		"	"												
3	0.70	3.50	10	26.81	do		"	"												
4	0.70	3.50	10	26.33	do		"	"												
5	0.70	0.70	10	26.88	2/6/09		"	"												
6	0.70	0.35	10	26.58	do		"	"												
7	0.84	0.42	12	23.76	2/13/09	566	245	110	87	65	57	48	1.59	.69	.31	.24	.18	.16	.14	3.31
8	0.77	0.38	11	24.10	do	590	250	120	87	65	57	48	1.66	.70	.34	.24	.18	.16	.14	3.42
9	1.54	0.77	11	25.77	3/6/09	705	410	255	102	68	63	45	1.98	1.15	.72	.28	.19	.18	.12	4.62
10	1.15	0.57	11	25.91	do	573	390	162	72	44	43	30	1.61	1.09	.45	.20	.12	.12	.08	3.67
11	2.30	1.15	11	23.38	3/13/09	701	336	192	111	70	50	20	1.97	.94	.54	.31	.20	.14	.06	4.06
12	3.07	1.54	11	23.92	do		398	192	107	67	56	32		1.12	.54	.30	.19	.16	.09	
13	2.30	1.15	11	25.90	3/20/09	735	327	205	130	80	45	45	2.07	.92	.58	.36	.22	.13	.13	4.41
14*	2.30	1.15	11	26.16	5/9/09	845	300	195	115	100	75	55	2.37	.84	.55	.32	.28	.21	.15	4.72
15	3.07	1.54	11	24.08	3/27/09	880	315	185	125	80	65	45	2.47	.87	.52	.35	.22	.19	.13	4.75
16*	3.07	1.54	11	22.98	do	645	245	150	100	60	45	40	1.81	.68	.42	.28	.16	.13	.11	3.59
17	0.84	0.84	12	24.70	4/3/09	1100	445	215	135	105	75	65	3.09	1.25	.60	.38	.30	.21	.18	6.01
18	0.42	0.84	12	26.91	5/9/09	1100	480	190	115	110	60	45	3.01	1.35	.53	.32	.31	.17	.13	5.82
19	0.84	0.00	12	27.00	4/10/09	840	260	125	80	70	55	40	2.36	.73	.35	.22	.20	.15	.11	4.12
20	0.00	0.00	12	26.41	do	1080	410	175	55	50	35	20	3.02	1.15	.49	.15	.14	.10	.06	5.11
21*	0.42	0.42	12	26.51	4/17/09	595	150	80	60	40	30	25	1.67	.42	.22	.17	.11	.08	.07	2.74
22	0.42	0.21	12	26.20	do	1325	320	180	125	95	70	55	3.72	.90	.51	.35	.27	.20	.15	6.10
23*	0.42	0.21	12	27.08	4/24/09	995	245	160	100	65	55	40	2.89	.69	.45	.28	.18	.15	.11	4.75
24	0.00	0.00	12	26.40	do	1040	260	160	110	75	65	45	2.92	.73	.45	.31	.21	.18	.13	4.95
25	0.00	0.00	12	27.34	5/9/09	1200	415	210	150	150	90	65	3.36	1.16	.59	.42	.42	.25	.18	6.38
26	2.00	1.00	12	28.09	do	890	390	185	105	95	55	40	2.60	1.09	.52	.29	.26	.15	.11	4.92
27	0.84	0.00	12	28.12	do	700	290	130	90	85	65	50	1.96	.81	.37	.25	.24	.18	.14	3.95
28	3.00	1.50	12	29.91	do	735	320	175	95	90	70	55	2.06	.90	.49	.26	.25	.20	.15	4.31


Total Flow
Alum added as Powder – Black Lines
Alum added in Solution – Red Lines
Total Flow in Grams
2400
2000
1600
1200
800
400
0
22
17
15
14
23
13
16
21
Time in Days
1
2
3
4
5
6
7
U. OF I. S. S. FORM 3


Daily Percolation
Alum added as Powder - Black Lines
Alum added in Solution - Red Lines
Percolation in Ounces per Square Inch
Time in Days
3.8
3.4
3.0
2.6
2.2
1.8
1.4
1.0
.6
.2
.0
1
2
3
4
5
6
7
22
17
23
15
14
13
16
21
R3
11.5
11.3
14
17
22
16
21

for this mixture 11 or 12 percent gave the best result . The percolation per day dropped rapidly for the first few days after which it assumed a more uniform rate of decrease. This may be due somewhat to the filling of the voids in the specimen by the precipitation from the water. The results of the total cumulative flow and of the daily percolation in ounces per square inch are plotted on pages 21 and 22 respectively.


Total Flow
Alum added in Powdered Form
Total Flow in Grams
2400
2000
1600
1200
800
400
0
Time in Days
1
2
3
4
5
6
7
25
17
18
20
26
24
19
28
11
9
27
10
8
7
U. OF I. S. S. FORM 3


Daily Percolation
Alum added in Powdered Form.
Percolation in Ounces per Square Inch per Day
Time in Days
3.4
3.0
2.6
2.2
1.8
1.4
1.0
.6
.2
.0
1
2
3
4
5
6
7
25
17
20
18
24
26
12
19
28
9
27
11
8
10
7
U. OF I. S. S. FORM 3

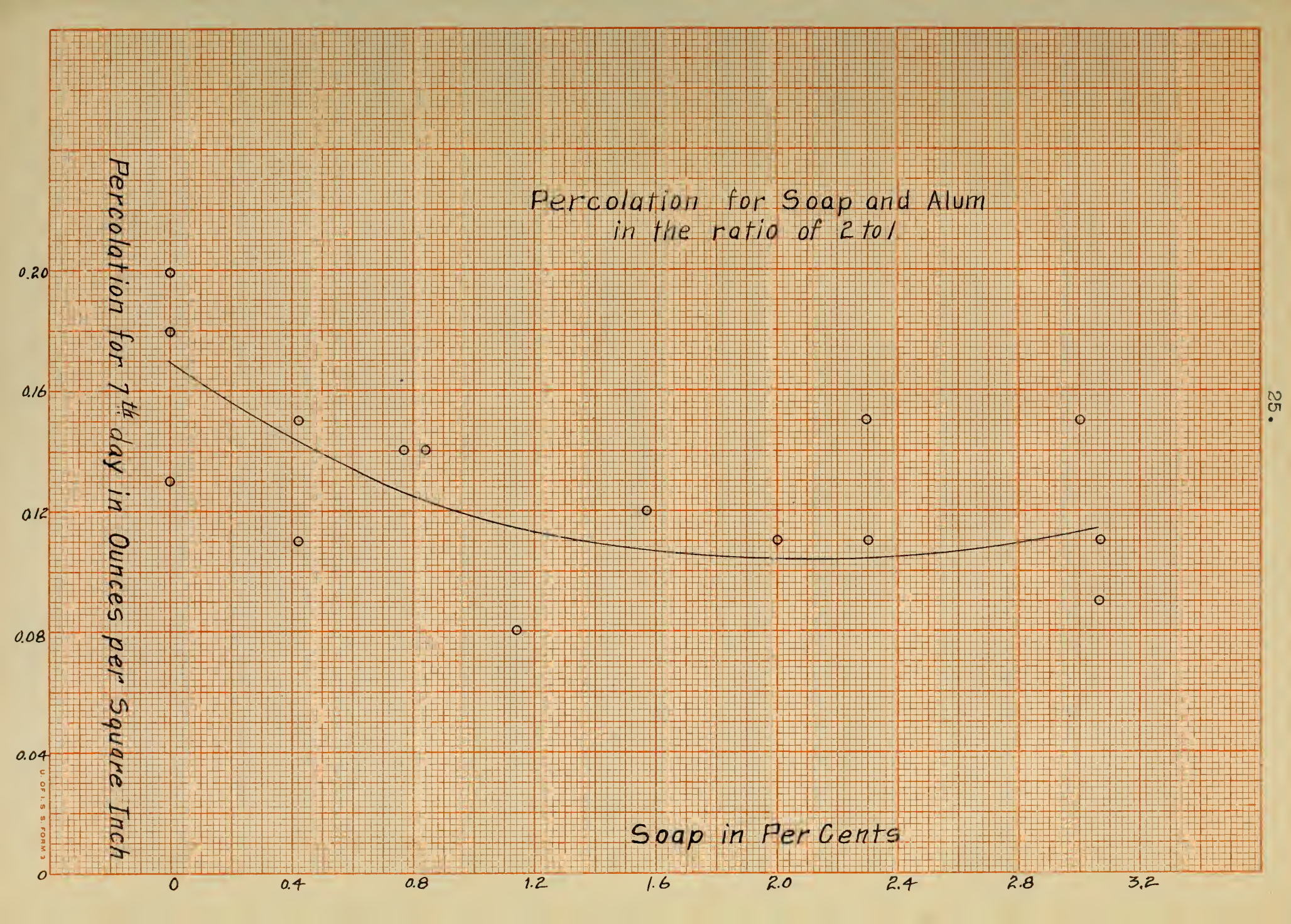
The percent of voids does not seem to be very closely connected with the amount of percolation but as the balances used in weighing the materials read only to 10 grams the determination of the percent of voids was not very accurate.

In general the tendency of the percolation curves does not show any decided change due to the addition of the soap and alum solution. This may be due to the small size of the material used, which made the concrete resemble mortar in its composition. The water pressure which is an important factor in determining the amount of percolation varied considerably thus producing a source of error in the results. To overcome this difficulty it would be advisable to use some method or device for obtaining uniform pressure for use in future experiments.

No conclusive deductions can be drawn as to the best ratio of soap to alum to be used, however, by taking the various ratio of soap to alum and comparing their average total flow as given in the table following, the solution of soap alone

Soap.	Alum.	Average Total flow in grams.	Average flow on 7th day in gr.
0	0	1600	43
2	0	1445	45
1	1	1550	45
2	1	1500	41

has the least percolation but the average rate of flow on the 7th day is in favor of the 2 : 1 ratio. The amounts of soap and of alum that might be used in the ratio of 2 :1 with the best results is shown by the curve on page 25 which was plotted after the percolation had become uniform. The curve shows that the disks which contained about 2% soap and 1% alum gave the best results. The variations in the results indicate the necessity of careful supervision and careful work on construction where waterproofing is being used.


Percolation for Soap and Alum
in the ratio of 2 to 1
Percolation for 7th day in Ounces per Square Inch
0.20
0.16
0.12
0.08
0.04
0
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
Soap in Per Cents
U. OF I. S. FORM 3